University of Illinois at Urbana-Champaign

NASA Ames Human Factors Symposium: History and Future Trends in Aviation Human Factors

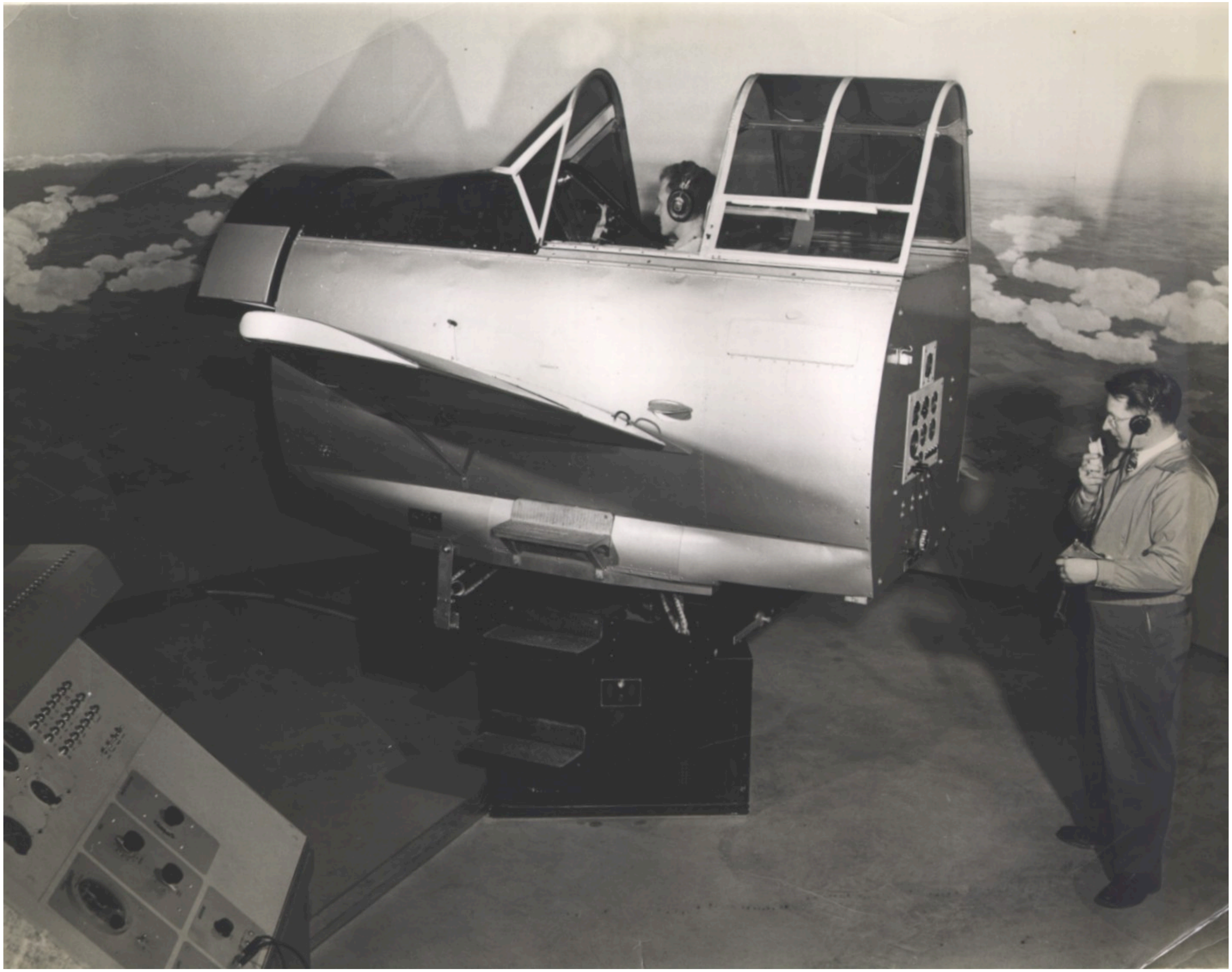
Christopher D. Wickens

Institute of Aviation

Aviation Human Factors Division

Human Factors and Aviation Safety: A Little Bit of History

- Paul Fitts and the post WWII years at Wright Patterson AFB:
  *sources of pilot error (“slips” of the hand between throttle and landing gear).
  *visual scanning and attention allocation.
- McRuer and Jex and the mathematical models of pilot flight control performance.
- Williams and Flexman at Illinois, & the studies of flight simulator transfer of training effectiveness.



The 1960s

Human factors is more than “nobs and dials.”

Standards & guidelines on color, font size and other legibility issues are **necessary**, but not sufficient.

Four themes emerged:

Four Themes of the 1970s

1. Information Transfer breakdowns. The communications accidents (Tenerife, Portland). NASA Ames and its role in Crew Resource Management CRM) development. A research "success story."
2. Transfer of training and transfer cost effectiveness. The benefits of low cost simulators. The Air Force's acquisition of the no-motion A10 simulator. More training/$. More reliable.

The 1970's

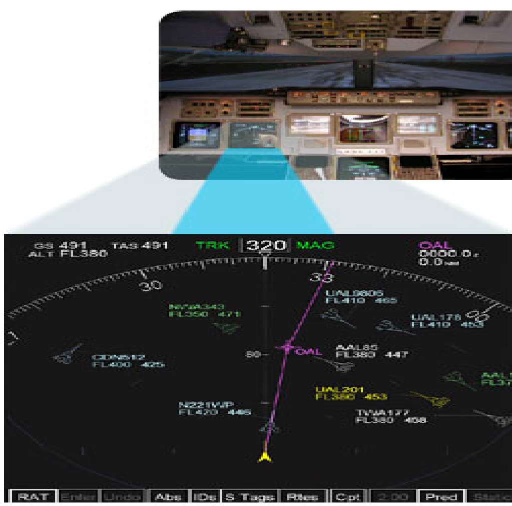
3. The glass cockpit and "soft" displays. Breaking free from the electromechanical bonds.

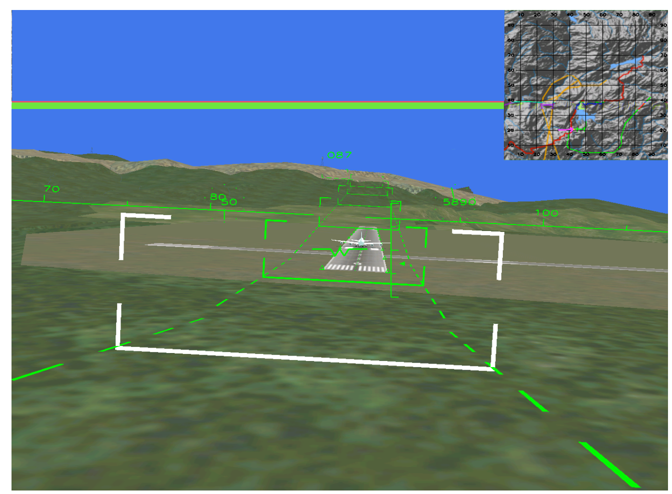
The Boeing Horizontal Situation Display (HSD).

The TCAS display (NASA Human Factors).

The early CDTI work.(NASA)

The development of the 3D Highway in the Sky.





4th Theme of the 80's & After: Automation

- The 737→757   3-crew→2-crew shift.
- The automation accidents (Everglades).
- The **classic** Wiener and Curry paper: "Flight deck Automation: Promises and Problems."
- Consequences:
- * The Sarter and Woods studies on FMS automation surprises.

 *Billings' 1997 Book (*Human Centered Automation*).

 *The 1996 Abbott et al report on automation guidelines.

 *The 1998 NRC report on ATC automation (*The Future of Air Traffic Control)*.

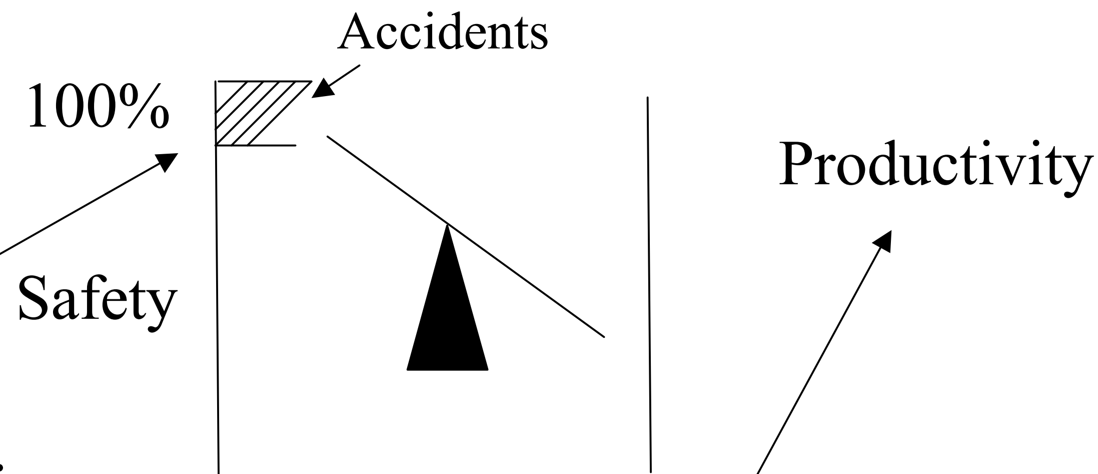
The Conferences

- The (late) *Annual Conference on Manual Control* (the "Annual Manual): NASA and the Air Force

  The birth of pilot performance models. (RIP)
- *The International Symposium on Aviation Psychology*. OSU → Dayton → OK City
- *Aerospace Medical Association* (ASMA) meetings
- HCI – *Aero Conference*
- HFES – *Aerospace Tech Group*

The Current State of Affairs

The safety-productivity “balance”



5-fold reduction

(Gore Commission

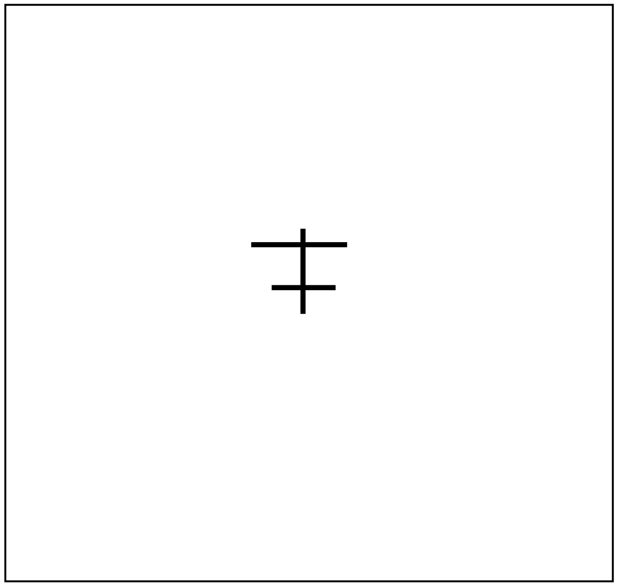
Task Force)

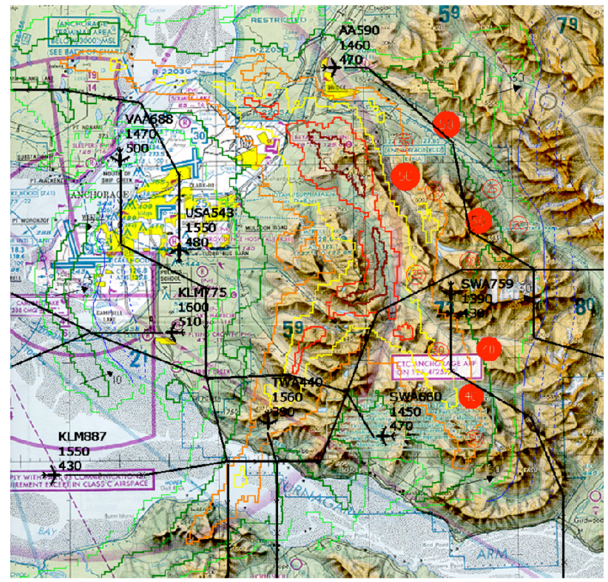
Pressures on productivity

$ Savings   Delays

Some (Aviation Automation Relevant) Things We Know About Human Performance

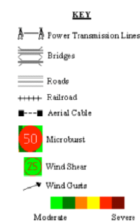
1. The generation effects and "OOTLUF" (out of the loop unfamiliarity). We remember states better when we actively chose those states.
2. Need to "know" the future. Unaided prediction is hard. ☹
   Accurate automation prediction is very useful. ☺
3. Humans <u>sometimes</u> respond poorly to unexpected events in time-critical environments.
4. Systems **will** fail, and Bainbridge's "irony of automation." (Higher reliability → rarer failure → poorer human response).
5. Information and clutter trade-off.





Will flight SWA660 pass over the city?

a) Yes
b) No



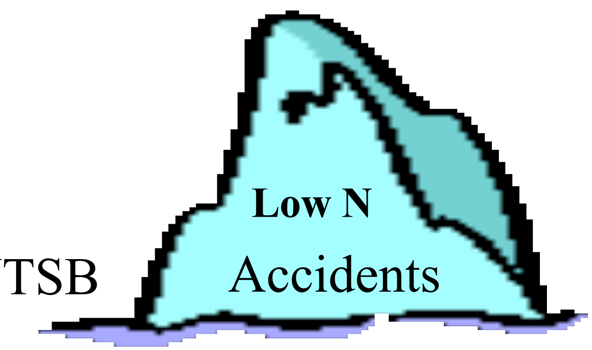
Future Trends in the Airspace

- 3D SVS displays, integrated hazard displays.
- Long duration space flight. (Needing to apply what we know about fatigue…The NASA studies).
- UAVs
- Free flight and the changing responsibilities between Air-traffic managers, pilots and automation (tools and UAVs).

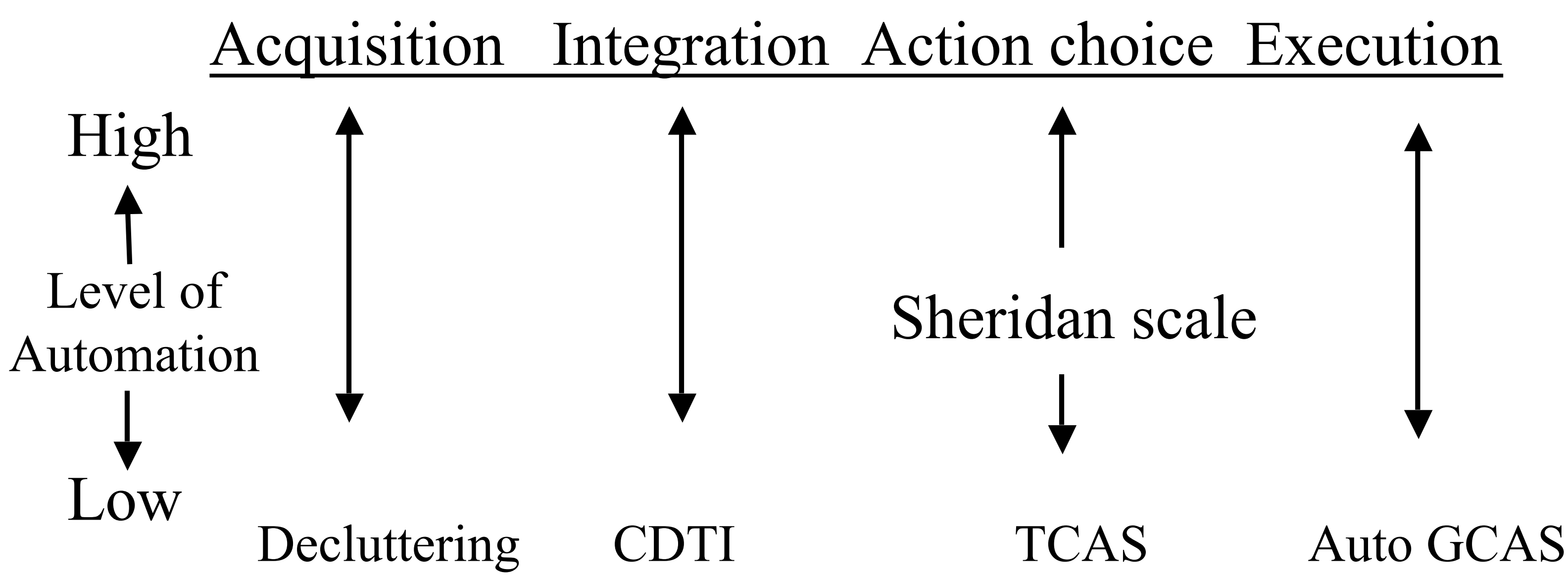
(Some) Key Future Human Factors Issues (My Biases)

How does (might) human operator error contribute to reduction in safety, in a **very safe** system? The "iceberg" metaphor.

Lobbying for safety from incident data. The need to establish causality from incidents → accidents.



The Parasuraman Automation Taxonomy

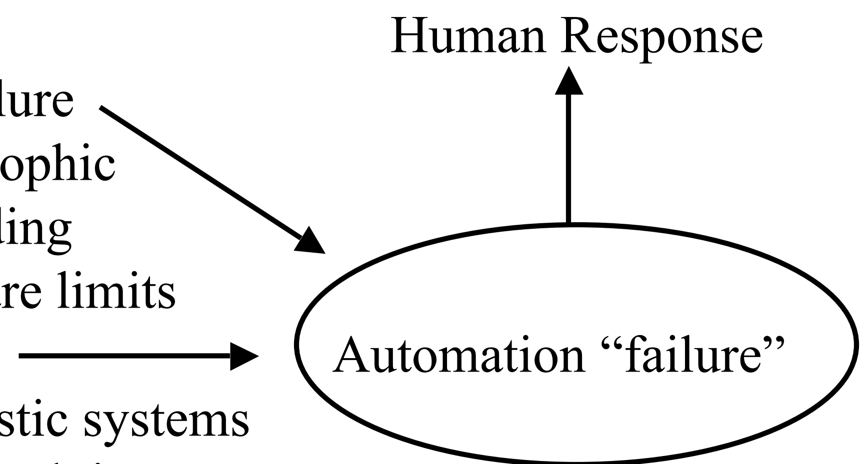


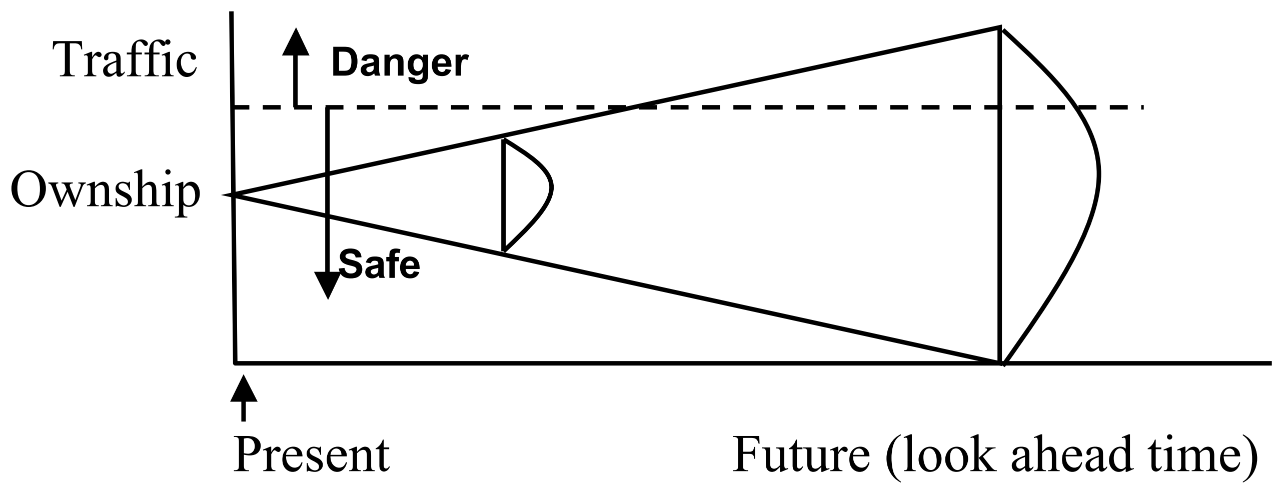
What is the optimal stage and level of imperfect automation?

Should automation levels be fixed? Or adaptive?

Given the increasing role of automation, and the need for human response to unexpected automation failures, what are the source of those failures?

- Failure modes analysis
- Fault trees
- System failure
- catastrophic
- degrading
- software limits
- Prediction
- stochastic systems
- Long look-ahead time



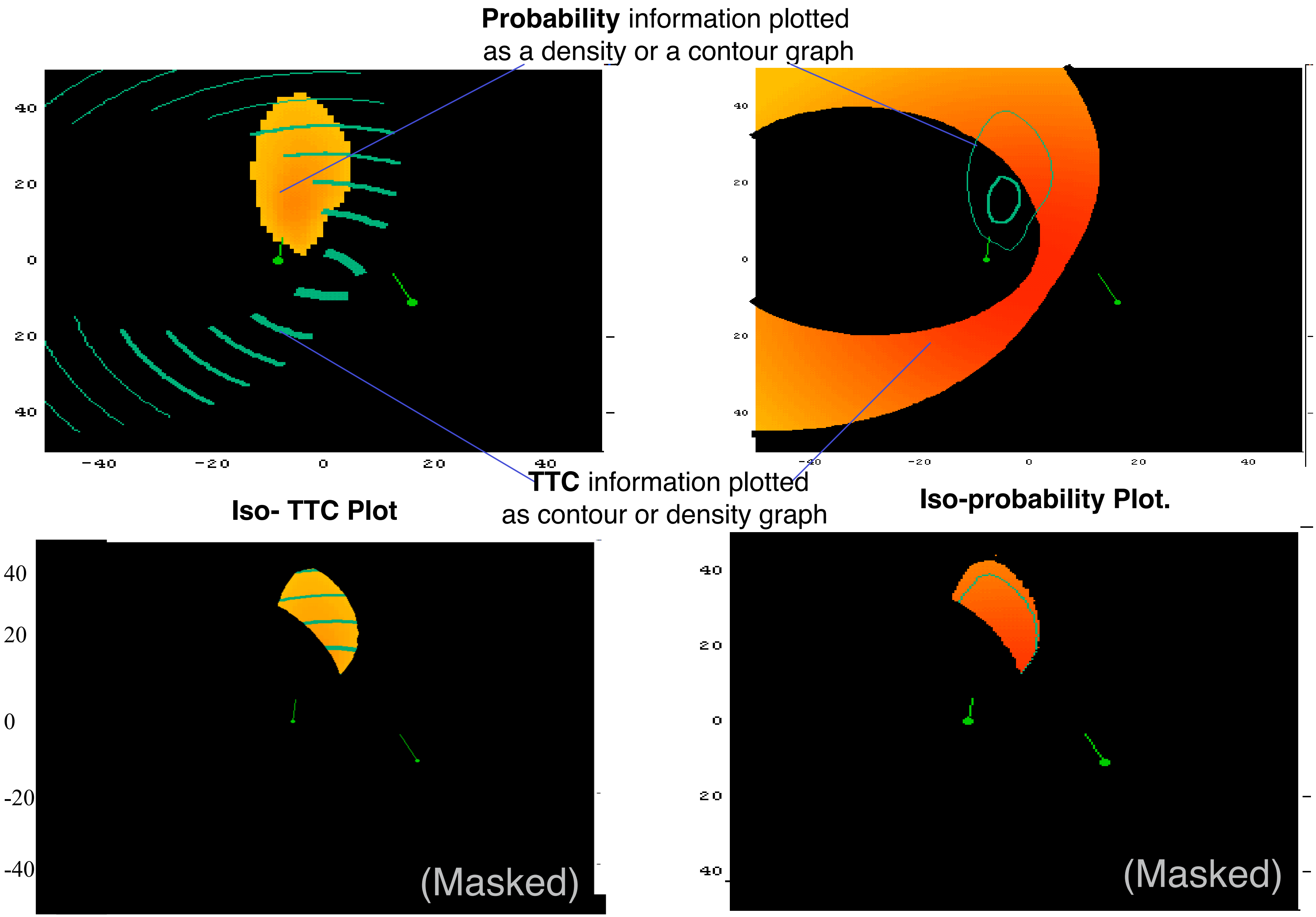


Advanced Display Research

- Value of predictor and probabilistic displays.
- Sarter: Icing display showing uncertainty of Neural Net automation reduces inappropriate use of automation.
- Milgram and Telner: Visualization of airspace uncertainty.

Predictive Probabilistic and Temporal Conflict Avoidance Displays

(courtesy of Jason Telner & Paul Milgram, University of Toronto)



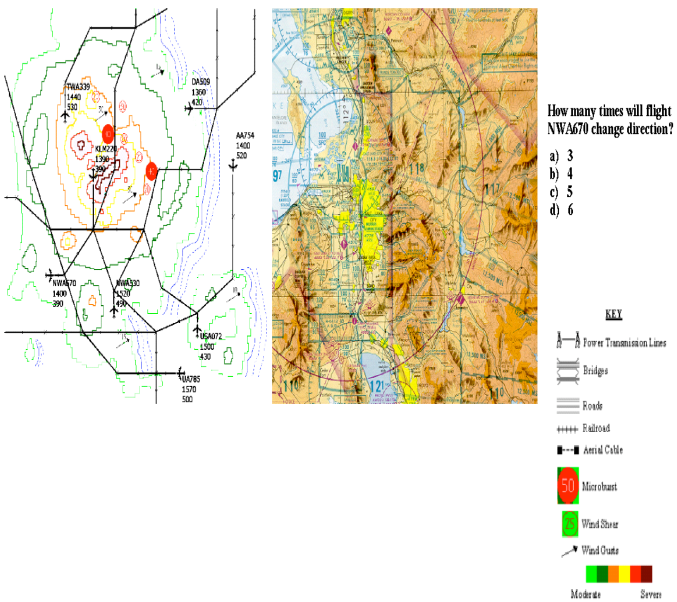
(TTC = Time-to-Conflict)

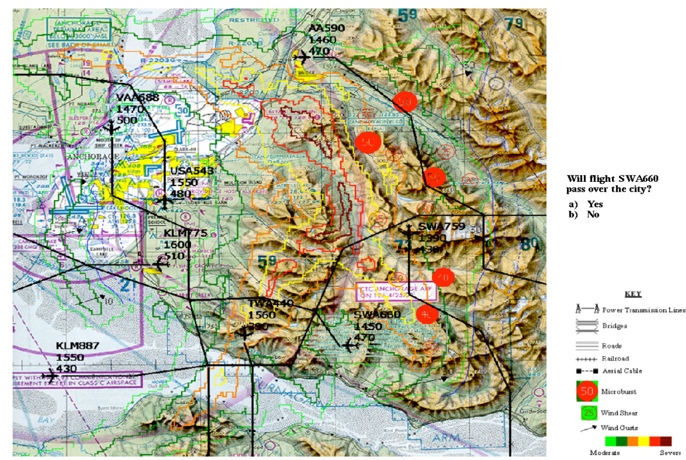
Some (Aviation Automation Relevant) Things We Know About Human Performance

1. The generation effects and "OOTLUF" (out of the loop unfamiliarity). We remember states better when we actively chose those states.
2. Need to "know" the future. Unaided prediction is hard. **Accurate** automation prediction is very useful.
3. Humans sometimes respond poorly to unexpected events in time-critical environments.
4. Systems **will** fail, and Bainbridge's "irony of automation." (Higher reliability→ poorer human response)
5. Information and clutter trade-off.

Advanced Display Research: Global-Local Displays

- Handling the information-clutter tradeoff.





- When is broad view needed to support global awareness? How to “drill down” to get narrow view for focused attention?

Advanced Display Research

Multi-sensory Integration

Vision Sound (NASA) Tactile

Redundant

Complementary

Independent

Training and Training Effectiveness

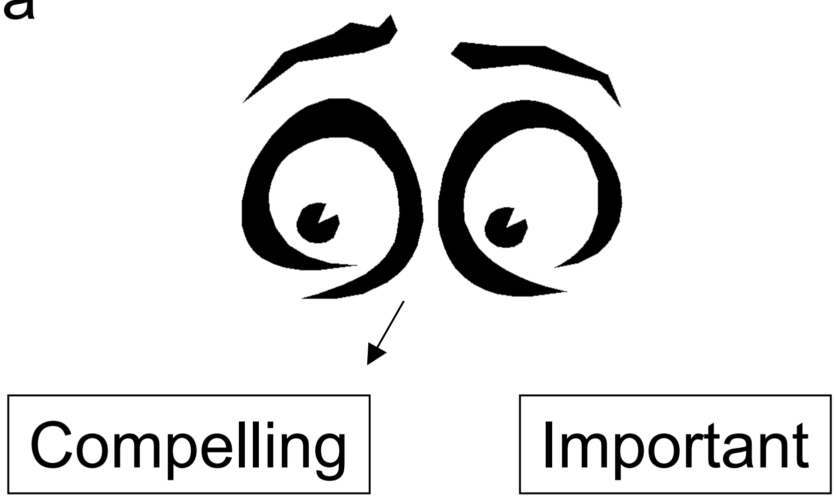
- Decision making and attention management. (cockpit task management) NASA
- Low cost (PC) simulation.
- Automation understanding. NASA
- Statistically reliable assessments of training effectiveness. What works?
- CRM training.

Emerging Psychological Constructs

- 1970s: Workload NASA (task shedding in overload remains an issue).
- 1980s: Situation awareness (hazard awareness and response to the unexpected remains an issue).
- 1990s: Automation trust and reliance. (Impact of system reliability and conflicting data sources remains an issue).
- 2000: Compellingness and attention tunneling.

Attentional fixation, attentional tunneling cognitive tunneling, cognitive fixation

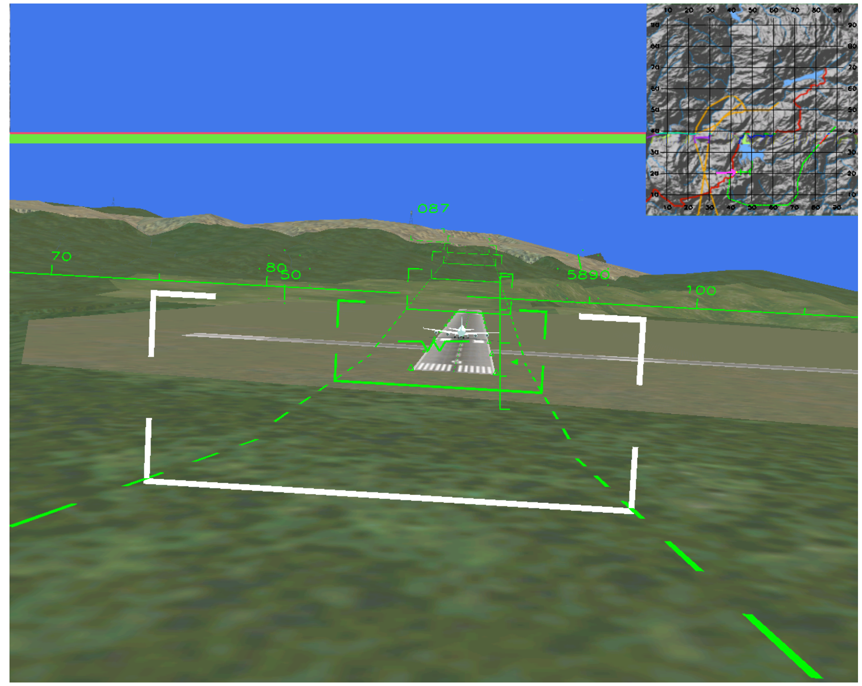
- Longer (than optimal) attention (visual) dwell **away from** an important area leading to:
- Performance failure on task supported by that area caused by:
- Compelling information (engaging task) supported by another area



Examples

- Stressful fault management (landing gear failure). Eastern Airlines Everglades crash (1972).
- Dismukes: head down failure analysis is “red flag” for task management.
- Cell-phone induced accidents of inattention. (cognition tunneling vision)
- HUD-induced fixation: the Fisher-Hanes & Price study. Replicated at Illinois (Fadden, Ververs, & Wickens), and at Boeing (Hofer, Braune, & Boucek). Failure to detect the unexpected runway incursion is amplified by the “compelling” HUD.

Does SVS and HITS <u>cause</u> attentional tunneling?

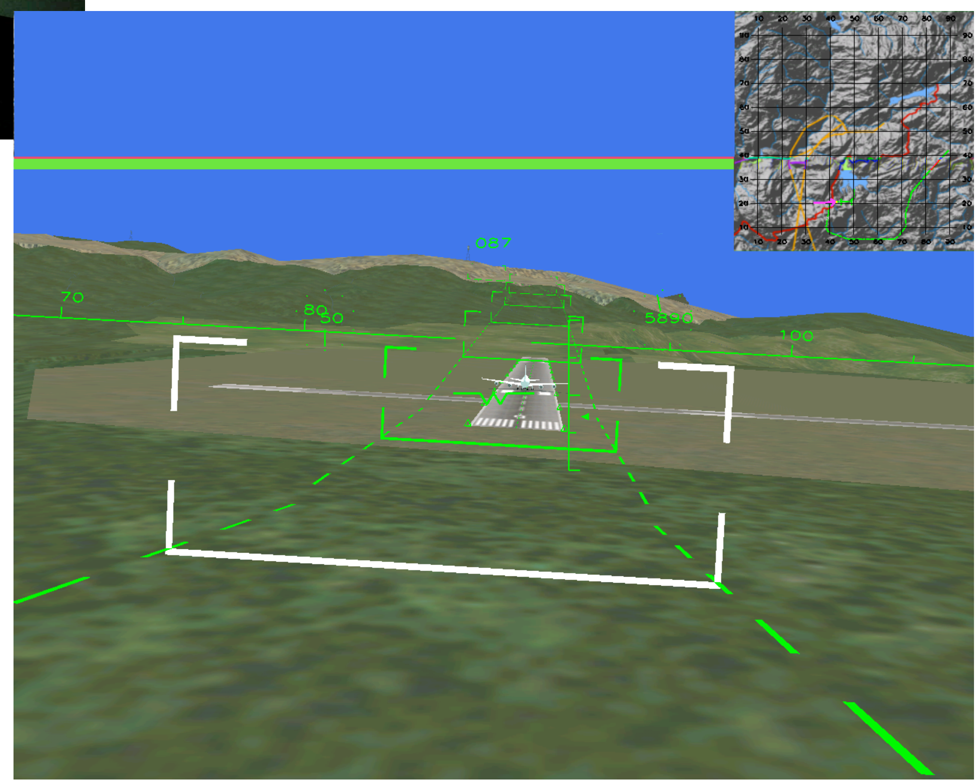


- SVS HITS does **not** cause tunneled disruption of detection of off-normal event visible **through** the SVS (Wickens et al., 2004)
- SVS HITS does **not** cause failure to notice weather changes on display away from the SVS (Iani & Wickens, 2004)
- SVS HITS <u>lowers</u> workload: More spare capacity for monitoring

BUT

HITS does cause failure to notice **very** unexpected event in the outside world

Outside World



SVS Display
Runway Incursion.
Tunnel Guides
Missed Approach

•HITS HUD delays runway incursion detection by 4 seconds (Fadden et al., 2001)

•HITS and SVS together cause failure to notice:

Runway offset (half of the pilots; Thomas & Wickens, 2004)

Transponder-off aircraft (half of the pilots; Thomas & Wickens, 2004)

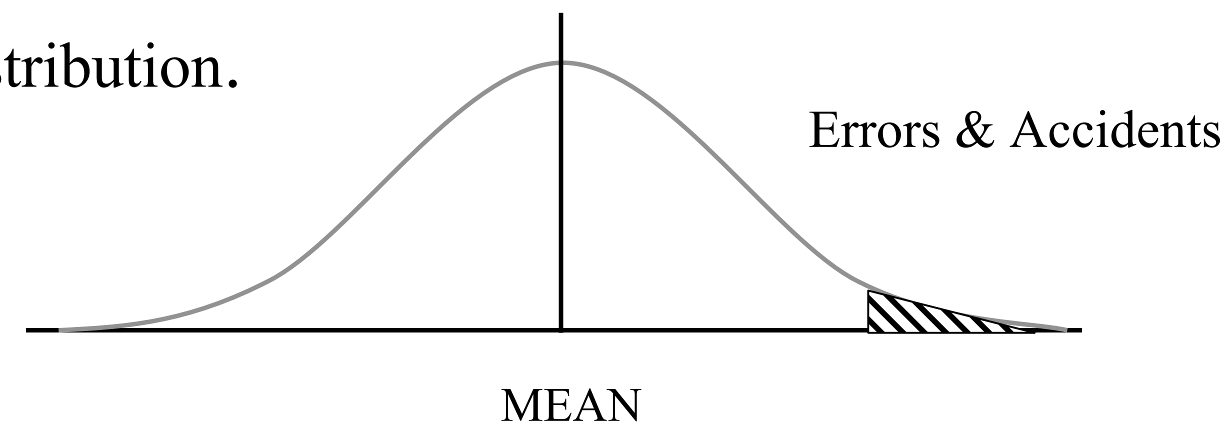
Missed approach tunnel following runway incursion directs pilots to fly into traffic only visible in outside world (most pilots) (Alexander, Wickens, & Hardy, 2003)

•Solution: train pilots on OW scan pattern with SVS.

Research Methodology

Understanding the "Psychology of Surprise" (response to unexpected failures).

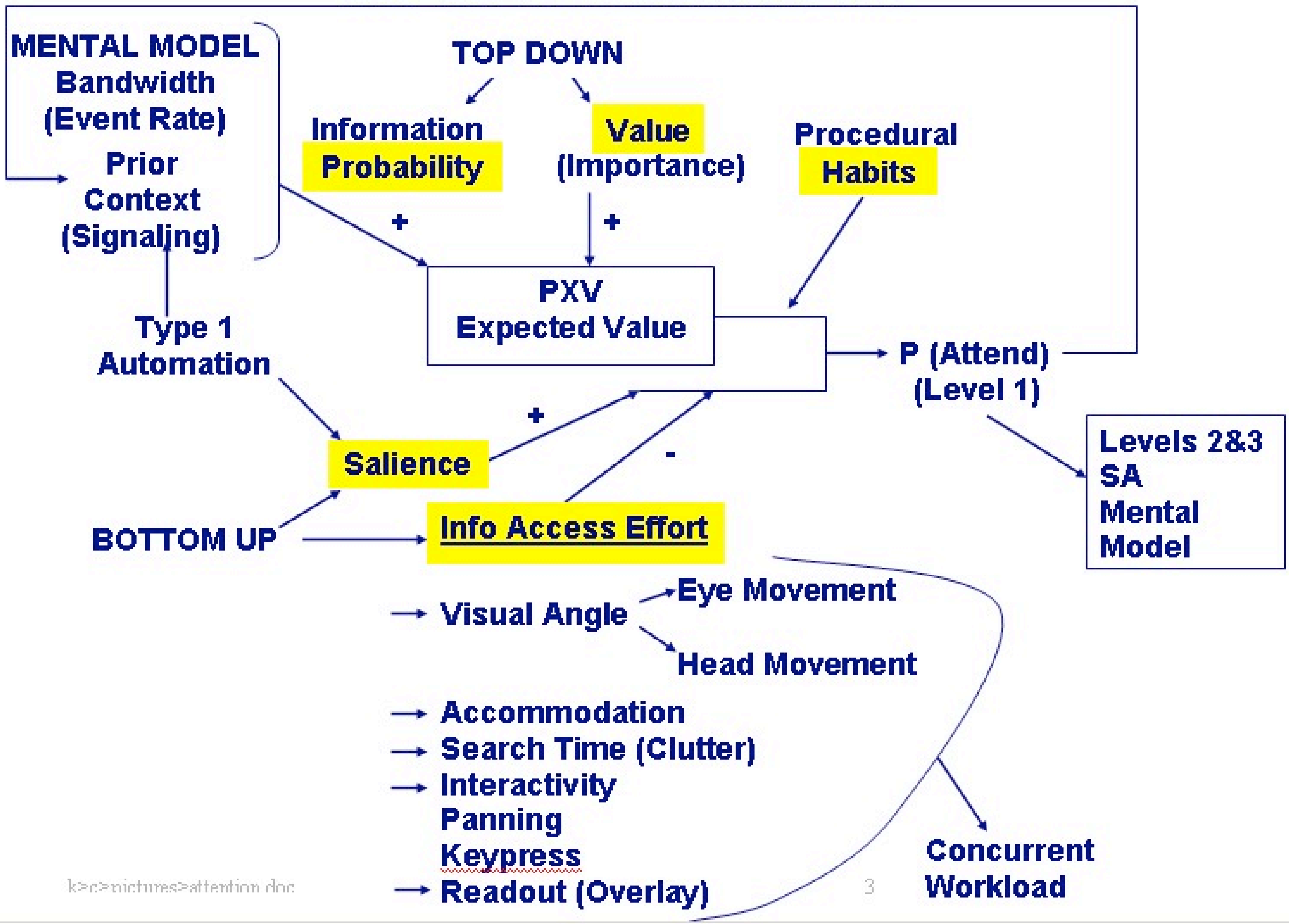
The challenge of low N responses to unexpected events. (If 1 pilot in 10 fails to respond to a runway incursion, this 0.10 frequency is "not significantly different from 0"). Problem with conventional statistics. Limitations of conventional statistics of the mean: Need to examine the "tails" of the distribution.



Research Methodology:
Beyond Guidelines and Experimentation: Computational Modeling

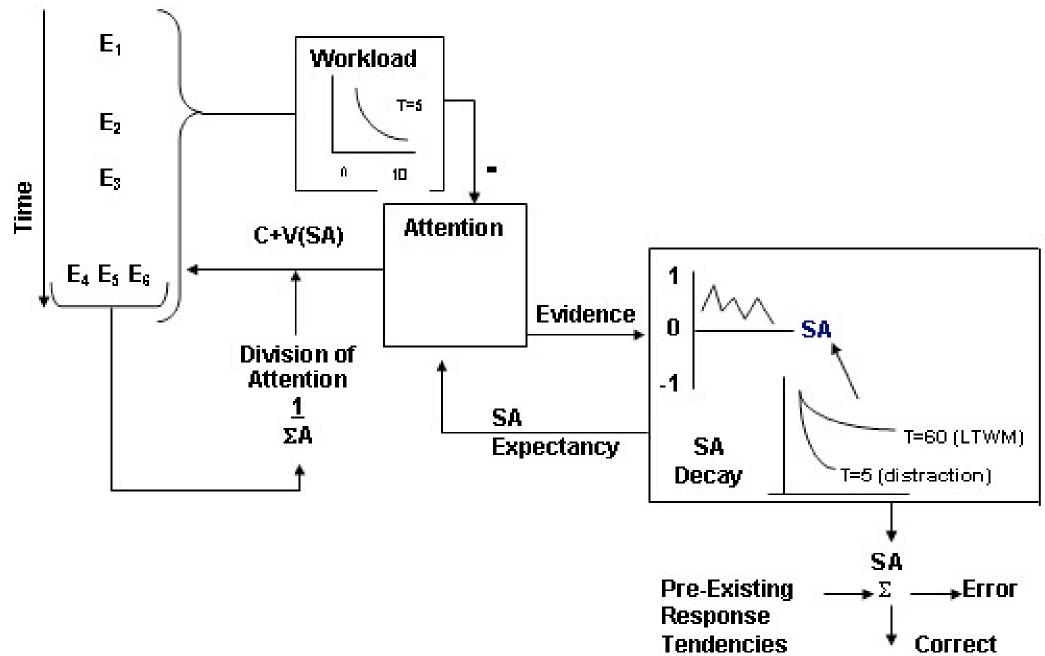
- Guidelines do not accommodate tradeoffs:
- Present necessary information; avoid clutter.
- Performance = a X info – b X clutter
- Experiments are slow, and/or lack statistical power for low N.
- Pilot opinion does not always predict response to off-normal events.
- NASA MIDAS

MODEL OF INFORMATION SAMPLING



EVENTS

E(C,V): Conspicuity, Info Value (relevance to situation of interest)



Research Methodology

Compiling, integrating and visualizing effects of **massive** data base of human factors literature:

Lab Research Simulation Incidents Surveys

Conclusions of Effectiveness

Models

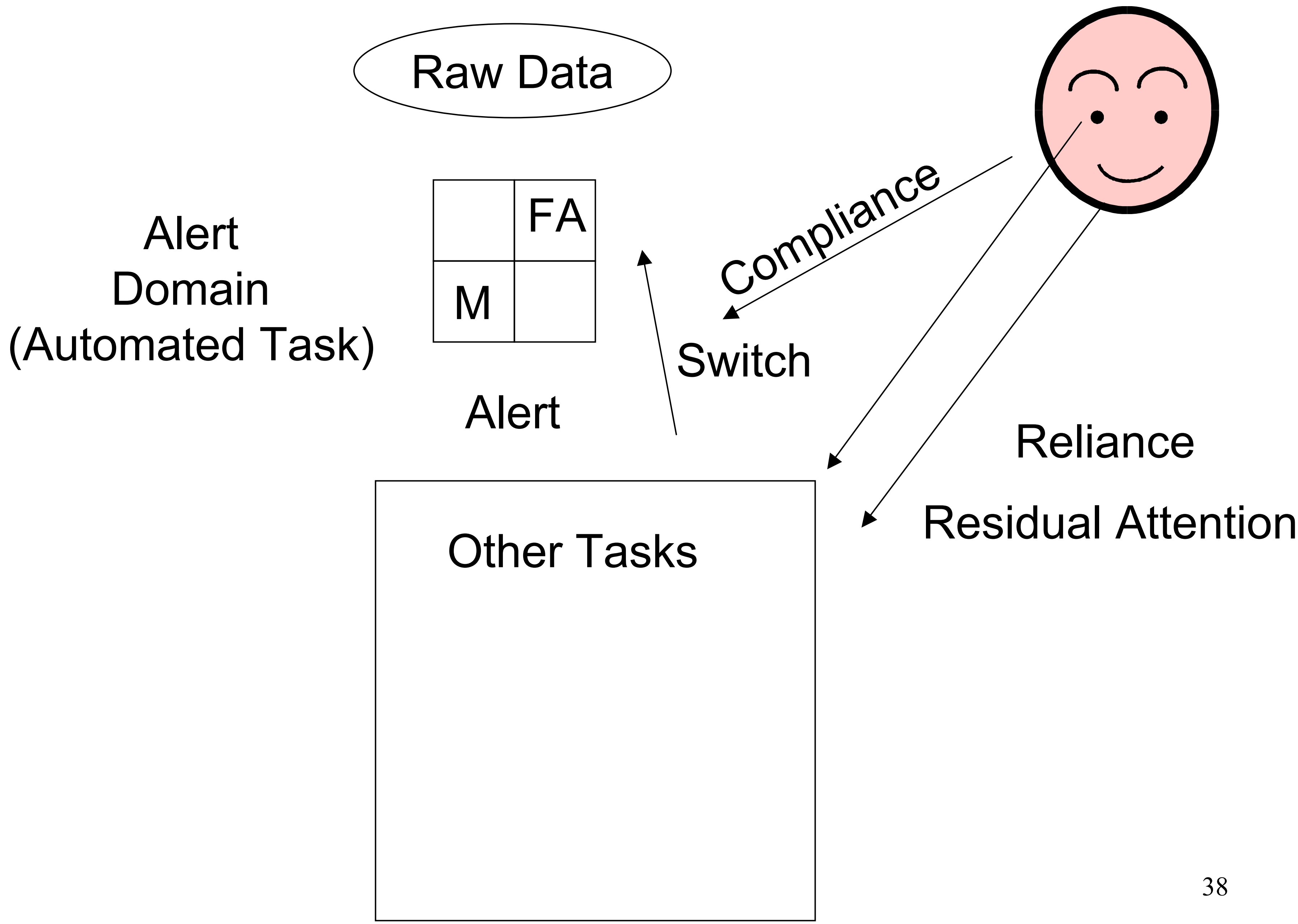
Conclusions

- Human Factors contributes.
- We need to better document our "success stories."
- Aviation Week and Space Technology

Meyer's Reliance-Compliance Dichotomy and Attention

•**Reliance →** amount of "reserve capacity" or "**residual attention**" that can be allocated to concurrent tasks.

Compliance →speed and probability of **switching attention** from concurrent tasks to automated alert domain, following an alert.


Raw Data
FA
M
Alert
Domain
(Automated Task)
Compliance
Switch
Alert
Reliance
Residual Attention
Other Tasks

TOO MONITORING

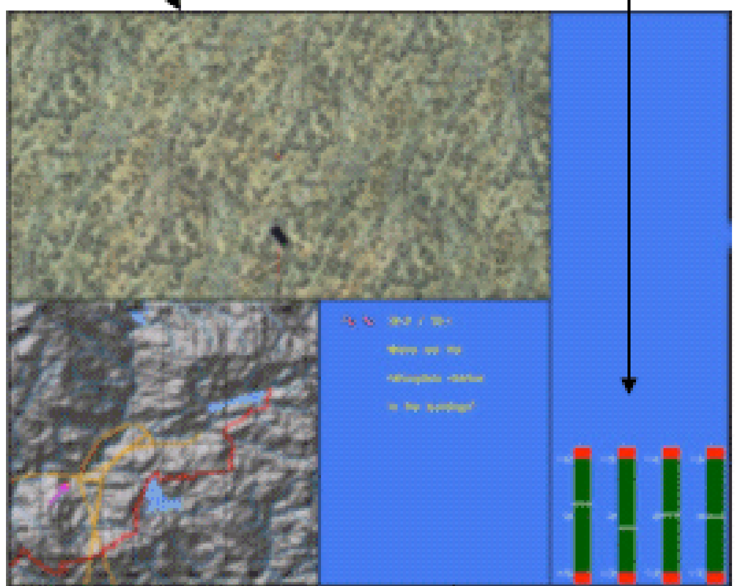
Secondary

Concurrent Tasks

Primary

3-D Image Display
Search for targets
Zoom & inspect these when found

System Gauges
Monitoring task
Identify failure when it occurs



2-D Navigational Display
Track UAV to reach waypoints

Message Box
Fly-to coordinates & report question

MISSION TASK

The Alarm Domain
Auditory Auto-Alert
60%-100% reliable

AUTOMATED TASK

System Failure (SF) Monitoring

Visual Scanning 60% Reliable FA Condition